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(54) CURRENT LIMITING CIRCUIT

(71) We, BROWN BOVERI & CIE AKTIENGESELLSCHAFT, of Kallstadter Strasse 1, D-6800 Mannheim-Kafertal, Germany, a German Body Corporate, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention relates to a current limiting circuit in which a semiconductor element, which is controllable by a semiconductor device, is connected in series with a resistor in a current-supply conductor. The circuit is used for example in the construction of fail-safe circuits for flameproof rooms in chemical plant and oil refineries. The electric circuits in rooms of this kind must have less energy than is required for igniting an explosable gas-air mixture. The critical ignition energy, for example in the case of the most readily ignited gas, namely oxyhydrogen gas, must remain below 20μWs.

A current limiting circuit is known in conjunction with the voltage stabilization of mains-operated apparatus (for example, German Auslegeschrift 1 413 242 and the literature references mentioned therein; German Offenlegungsschrift 2 143 908). In this context it is also known to provide overload protection.

The prior art also discloses a circuit (Messrs. Hartman & Braun) in which the power which occurs at the output of the fail-safe circuit has a hyperbolic current-voltage characteristic and remains below the maximum permissible current limit value. However, the effective power available in the fail-safe circuit is relatively small.

A publication (by Messrs. Stahl) relating to Zener diode barriers discloses a circuit in which a transistor carries the load current in normal operation. A thyristor fires if the current is excessive and drives the transistor to cut-off. Automatic reclosing is obtained by the current dropping below the value of the thyristor holding current. The thyristor holding current which occurs in the event of an output short circuit is however a disadvantage: it causes an output arc which cannot entirely disappear because full current flow through the transistor commences after current flow drops below the thyristor holding current, the aforementioned full current flow supplying the arc with fresh energy. This may exceed the ignition energy.

To comply with certain safety regulations the electrical energy in flameproof rooms must not exceed 20μWs and a rupturing time of less than 5.3μs must be obtained given the desirable values of a short circuit current of 150 mA. at 25 volts.

The invention seeks to provide a circuit which can disconnect the output from the input within the above-mentioned rupturing time but is nevertheless capable of delivering a high power to the output under normal conditions.

According to the invention, there is provided a current limiting circuit comprising a semiconductor element the switching path of which is connected in series with a resistor and, in use, is connected in a current-supply conductor, and the control electrode of which is connected to a constant-current source serving to maintain the said semiconductor element in the conductive state during normal operation, and a semiconductor device connected across the resistor and operative in response to the current in the resistor exceeding a predetermined limit, rapidly to render the semiconductor element non-conductive.

The said semiconductor element is conveniently a transistor provided with base current from the constant-current source to maintain it in the conductive state. The semiconductor device is conveniently a unijunction transistor which becomes conductive when the output current reaches the predetermined limit, and thus drives the series transistor to cut-off. The series transistor and the unijunction transistor

co-operate in such a way that the current supplied at the output is limited. The series resistor defines the output current limit.

The substantially higher load-bearing capacity of the present fail-safe circuit is particularly advantageous. A load current of 100 mA can be offered to the load, given a supply voltage of 24 V. The system is switched off at higher load currents within the extremely short time of less than 1 μ s. The application of the circuit in fail-safe circuits can eliminate the use of power transistors in the series circuit.

One embodiment of the circuit according to the invention is explained hereinbelow with reference to the accompanying drawing.

The voltage +U is applied to the input terminal A. A transistor V_2 is connected between the input terminal A and the output terminal B. A resistor R_1 is connected between the emitter of the aforementioned transistor and the input. The base of the transistor V_2 is connected through a diode V_3 and a FET V_4 to ground potential. The FET V_4 operates as a constant current device. The gate electrode of the FET V_4 is connected to the source electrode. A *p*rogrammable *u*nijunction *t*ransistor (PUT) V_1 is connected between the input A and the FET V_4. The cathode of the PUT V_1 is connected to the cathode of the diode V_3 and to the drain of the FET V_4. The control electrode of the PUT V_1 is connected through a resistor R_2 to the junction between R_1 and the emitter of V_2. The anode of a diode V_5 is connected to ground potential and the cathode to the output terminal B.

The circuit operates as follows.

Under normal conditions current flows through the base of the transistor V_2, through the diode V_3 and through the FET V_4. This current drives the transistor V_2 into the conductive state, i.e. the input A is connected to the output B. The FET V_4 operates under constant-current conditions, i.e. it operates at constant current over a wide voltage range and supplies the base current for driving the transistor V_2 into the conductive state.

If the load current I_K at the output B is increased a voltage drop will occur across the resistor R_1 to function as control voltage for the PUT V_1. When this voltage drop has reached the necessary magnitude the PUT V_1 will be driven into the conductive state and carry the current which hitherto flowed to the base of the transistor V_2, i.e. V_2 is driven to cut-off.

The residual voltage of the PUT prevents the transistor V_2 being completely switched off. The diode V_3 which is operated in the forward direction prevents the residual anode-cathode voltage of the PUT V_1, amounting to approximately 1 V, from driving the transistor V_2 into the conductive state. The diode V_5 operates as free-wheeling diode and is intended to clip negative voltage peaks when inductive loads are switched off.

The unijunction transistor may be replaced by a thyristor, an interconnection of two transistors which function as a thyristor, or by a comparator circuit of which the output is connected to a reset-table bistable circuit serving to switch off the transistor.

WHAT WE CLAIM IS:—

1. A current limiting circuit comprising a semiconductor element the switching path of which is connected in series with a resistor and, in use, is connected in a current-supply conductor, and the control electrode of which is connected to a constant-current source serving to maintain the said semiconductor element in the conductive state during normal operation, and a semiconductor device connected across the resistor and operative, in response to the current in the resistor exceeding a predetermined limit, rapidly to render the semiconductor element non-conductive.

2. A circuit according to Claim 1 in which the said semiconductor element is a transistor, and a diode is arranged in the base circuit of the transistor to prevent any residual voltage across the said semiconductor device when the predetermined current limit is exceeded from maintaining the transistor conductive.

3. A circuit according to claim 1 or 2 in which the said semiconductor device is a programmable unijunction transistor.

4. A circuit according to Claim 3 in which a protective resistor is arranged to prevent extinction of the said unijunction transistor.

5. A circuit according to Claim 1 or 2 in which said semiconductor device is a combination of two transistors adapted to function as a thyristor.

6. A circuit according to Claim 1 or 2 in which said semiconductor is a thyristor.

7. A circuit according to Claim 1 or 2, in which the semiconductor device includes a comparator connected across the resistor and a resettable bistable circuit connected to the comparator and arranged to render the semiconductor element non-conductive when the predetermined current limit is exceeded.

8. A circuit according to any of Claims 1 to 7, in which a diode is connected to the output of the circuit as protection for switching off inductive loads.

9. A current limiting circuit substantially as herein described with reference to the accompanying drawing.

MARKS & CLERK.

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